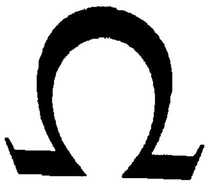
U.S. COAST GUARD

RADIONAVIGATION BULLETIN

Fall/Winter Issue 1996, Number 31



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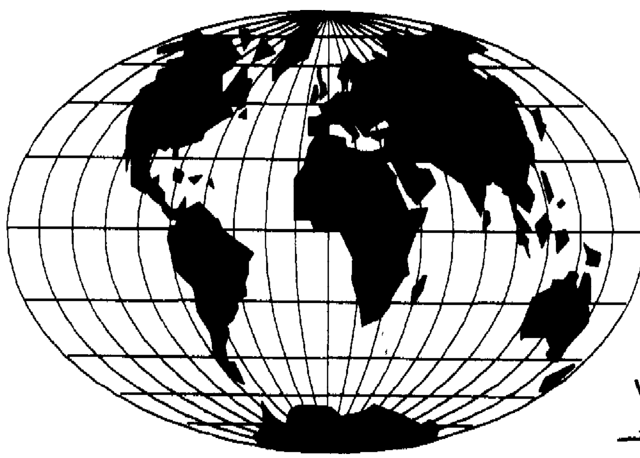

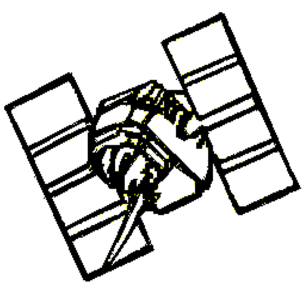

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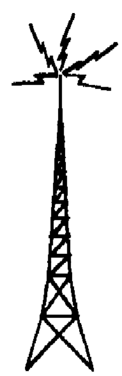

RADIOBEACONS

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RADIONAVIGATION BULLETIN

U.S. Coast Guard
Navigation Center
7323 Telegraph Rd.
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Issue Number 31
Fall/Winter 1996

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From the NAVCEN Commanding Officer

Hello. It's my pleasure to lead off this issue of the Radionavigation Bulletin—my first as Commanding Officer of the Coast Guard's Navigation Center (NAVCEN).

On June 25, 1996, I relieved my good friend, Captain Bob Wenzel, as NAVCEN's CO. As I said during the change of command ceremony, this is the job for which I have trained throughout my career. I've served as navigator aboard a buoy tender, as a Loran project engineer at the Electronics Engineering Center (EECEN), Loran operations officer in Activities Europe (ACTEUR), and in various Headquarters navigation program and support manager roles. The job of NAVCEN CO draws on all these elements of my background. The NAVCEN operates the Omega, Loran, and Differential GPS radionavigation systems, and the radiobeacon navigation aids; it provides the Navigation Information Service (NIS) directly to the public, and through it facilitates communications between navigation users and the Federal Government's service providers; NAVCEN also hosts the Boating Safety Hotline; it even serves an engineering support role as the System Management Engineering Facility (SMEF) for Omega; and finally, NAVCEN is the host, executive secretary, and support provider for the Civil GPS Service Interface Committee (CGSIC). As a collateral duty, I serve as the Deputy Chairman of the CGSIC, which is currently chaired by DOT's Deputy Assistant Secretary for Transportation Policy, Mr. Joseph F. Canny.

Although NAVCEN is primarily an operational command, it is unique in that it is also tasked with functions of traditional Headquarters program management staffs. For example, NAVCEN personnel frequently serve as US representatives to technical discussions regarding standards for Electronic Chart Display and Information Systems (ECDIS) and other emerging technology-driven navigation issues. Through the NIS, we are also learning of new navigation information needs and developing or testing methods to support them. We do this through our home page on the World Wide Web, automated fax on demand, bulletin board services, and other state-of-the-art information management tools. In the navigation arena, user needs are changing rapidly, and we are working in partnership with HQ program and support managers, other operational commanders, and other support commands to meet these. An example is our prototype project with the First Coast Guard District in Boston to further automate development and improve the accuracy and user-selectability of Local Notice to Mariner information available on our home page.

If you've followed my remarks this far, I hope you've noted how excited I am about the future of radionavigation and navigation information systems. You may also have noted that we missed the Spring/Summer 1996 edition of this Radionavigation Bulletin. I personally think this Bulletin is a useful way of sharing information throughout the radionavigation community. But it is only useful if we have information to disseminate—for the Spring/Summer 1996 edition, we didn't have enough articles in a timely manner to assemble a Bulletin. We have some good articles for this one, but I'm concerned about the future. Please signal your support by contributing your material for the next one as soon as possible. Our deadlines are March 1 for the Spring/Summer edition and September 1 for the Fall/Winter edition; we need about a half dozen quality articles of 300-500 words, for each edition.

Let me end on a positive note. These <u>are</u> exciting times in radionavigation developments, and also in the innovative use of both radionavigation systems and information technology. I'm delighted to be here at the Navigation Center, and I look forward to continue using this Radionavigation Bulletin to share ideas to improve our community's performance and innovative contributions.

CAPT James T. Doherty

LORAN-C CONSOLIDATED CONTROL SYSTEM (LCCS) PROJECT

Progress toward implementation of LCCS continues. The project, which replaces aging Loran control equipment and relocates the control sites, will allow personnel reductions for these missions by 50%.

Three of the six U. S. and Canadian Coast Guard control stations are converting to LCCS operations. Control Station Middletown, CA, which oversees the 8290 North Central Chain and the 9940 U. S. West Coast Chain, is scheduled to relinquish control to the Navigation Center Detachment in Petaluma, CA, mid-June 1997. Control operations in Malone, FL, for the 7980 Southeast U. S. Chain and the 9610 South Central U. S. Chain, will be transferred to the Navigation Center in Alexandria, VA, July 1997. When control operations for the 9960 Northeast U. S. Chain and the 8970 Great Lakes Chain from Sencea, NY move to Alexandria in August 1997, the project will be complete.

The transition from current control operations to LCCS control will be transparent to the user. Middletown, Malone, and Seneca will continue as Loran-C transmitting stations. None of the operating parameters will change. The only indication the user will have that there has been a change is the difference in contact telephone numbers.

LT J. Elbe, NAVCEN

Selections from "USCG 21st Century Buoy Tender"

The following are sections from a paper by **Joseph W. Spalding, Robert D. Crowell and Lee A. Luft** of the U.S. Coast Guard Research and Development Center in Groton, Connecticut. The paper was recently presented at the Institute of Navigation GPS '96, Ninth International Technical Meeting, September 18, 1996.

The entire paper is available from the NIS internet site and the NIS BBS.

ABSTRACT

The ships that will tend USCG floating aids to navigation in the next century are being built today. The lead ship in the new class of sea-going buoy tenders, the USCG Cutter JUNIPER, underwent test and evaluation this past spring and summer. Through the use of differential GPS and an integrated approach to the ship's navigation and control systems the ship is capable of transiting and positioning itself automatically at the assigned position to set and work on navigation buoys. This capability along with other automation on the buoy deck and in the engine room allows for a reduction in manning for this vessel to 40 as opposed to 55 people on board its predecessor, the 180' seagoing buoy tender.

This paper describes the testing of the ship's DGPS performance and the performance of the dynamic positioning system to ensure that the ship will meet its operational requirements. The use of a real time kinematic DGPS as the truth system is detailed, along with the development and capabilities of the real time data collection and analysis program, SHIPTEST. Results of the testing, static and dynamic DGPS accuracy, and ship's station-keeping accuracy are presented.

INTRODUCTION

Beginning in 1979, the Coast Guard began a program to replace its aging fleet of buoy tenders. In 1985 the Secretary of Transportation approved the Mission Needs statement and the program proceeded to eventual procurement of the USCGC JUNIPER, delivered to the Coast Guard in January 1996. In March and July of 1996 the USCG R&D Center conducted an independent evaluation of the accuracy of the USCGC JUNIPER's (WLB-201) differential GPS and dynamic positioning system. This evaluation was done to support the Independent Operation Test (IOT) team located at R&D Center in their task of independent operational test and evaluation of the JUNIPER class. The equipment and expertise developed at the R&D Center in its GPS research was ideal for this evaluation. The testing was conducted in two separate sessions, March 26-27 in Lake Michigan near Milwaukee, Wisconsin and July 15 in Long Island Sound, New York.

BACKGROUND

The Coast Guard maintains a system of short range visual aids-to-navigation consisting of lighted and unlighted buoys, lighthouses, ranges and other fixed structures. Aids-to-navigation teams, construction tenders, and a variety of coastal and sea-going buoy tenders maintain this system to support maritime commerce and ensure marine safety in U.S. waters. The Coast Guard currently uses approximately 40 Coast Guard cutters known as buoy tenders to service floating aids-to-navigation. Six 133' White class coastal buoy tenders (built in 1943), four 157' Red class coastal buoy tenders (built from 1965-1972) and twenty six 180' BALSAM class sea-going buoy tenders (built from 1942-1944) make up the majority of this fleet of aging but serviceable vessels.

In January 1993 the Coast Guard awarded the first contract in more than 50 years for a sea-going buoy tender to Marionette Marine corporation of Marinette, Wisconsin [1]. The Coast Guard specified the performance of this vessel in the circular of requirements. Along with requirements for Buoy Tending and Ship's Characteristics was a section entitled Special Features. Under Special Features was the requirement:
"*Hold ship's position and heading within 2m accuracy using visual and differential electronic methods. Allow the cutter to approach, maneuver, and automatically maintain position within a 10m radius*."
The JUNIPER is designed to accomplish this using its dynamic positioning system (DPS). The DPS, by Nautronix Inc., consists of a high speed central processor which manages the autopilot and joystick/dynamic positioning functions.

The autopilot function is used for transiting and uses only steering and main propulsion. Bow and stern thrusters are not operational in this mode. The autopilot can be configured to steer a selected course based on the gyrocompass or magnetic compass, set to maintain a particular speed, or can maintain a desired navigation track between waypoints.

Joystick/dynamic positioning mode is used for low speed maneuvering and was the subject of this testing. In this mode, the DPS controls the main propulsion and bow and stern thrusters. The rudder is placed amidships and the steering system placed on standby. Three of the modes of DPS operation that provide positioning are full manual, hold heading, and hold position. Full manual allows simple joystick control for the operator to manually position the vessel. Hold heading automatically maintains the heading of the vessel. Hold position automatically maintains the position of the vessel. In hold position mode the vessel heading may be manually controlled or automatically controlled by engaging the hold heading simultaneously with the hold position function.

USCGC JUNIPER (WLB-201)
Principal Characteristics

Length overall .... 225 ft-9.5 in.
Length between perpendiculars .... 206 ft-0 in.
Beam .... 46 ft-0 in.
Draft .... 13 ft-0 in.
Displacement .... 2000 LT
Speed at 80% maximum continuous rating .... 15 knots
Propeller .... 4 bladed, controllable pitch, 10 ft dia.
Engines (2) .... 3100 bhp each, at 900 rpm
Bow thruster .... 440 hp, tunnel type, 9300 lb thrust
Stern thruster .... 550 hp, tunnel type, 11400 lb thrust

TEST EQUIPMENT DESCRIPTION

The truth positioning system consists of an independent survey grade GPS equipment capable of achieving 3 centimeter level accuracy within 10 miles of its dedicated reference station. For terminology purposes the system will be referred to as the "RTK-GPS" (Real-Time Kinematic) to differentiate it from the Coast Guard beacon-based DGPS service. The shore system consists of an Ashtech Z-12 GPS configured as an RTK-GPS base station, Pacific Crest 35 watt VHF radiomodem transmitter, and antennas. The shipboard system consists of an Ashtech Z-12 GPS configured as the RTK-GPS rover station, Pacific Crest 2 watt VHF receiver, and data collection computer, a Compaq 486/66 Portable computer.

The system under test consists of the DGPS on board the USCGC JUNIPER, a Leica 9212 12 channel GPS receiver and an MX 50R differential beacon receiver. The JUNIPER was using the Coast Guard DGPS broadcast from Milwaukee, Wisconsin during March tests and from Chatham, Massachusetts, during the July test. In this configuration the positioning performance is specified to have 2 meters accuracy. The other subject of the test is the ship's Dynamic Positioning System (DPS), a collection of control and machinery systems specified to maintain the position of the vessel within 10 meters of the desired position.

The two systems are compared using a program developed by the R&D Center called Shiptest. Shiptest was designed to take the two NMEA 0183[2] GPGGA inputs, synchronize them and compare the positions. All position inputs were adjusted (moved) to a common location on the ship, identified as the master reference point (MRP) in order to compare the system under test with the truth system. A file containing precise measurements describing the locations of the GPS antennas relative to the MRP was used to initialize the Shiptest program. The NMEA 0183 GPHDT (heading) input from the ship's gyrocompass was applied to each position measurement to determine the proper adjustment (offset) necessary.

DGPS ACCURACY TEST

The objective of this series of tests is to determine the accuracy of the ship's DGPS. For this test, data was collected directly from the RTK-GPS and from the ship's system via the Local Area Network (LAN). LAN data was provided via a LAN Interface Unit with an RS-232 port. LAN data consisted of ships NMEA data; GGA (GPS position) and HDT (true heading, gyro). This data was compared to the RTK-GPS position in NMEA GGA format and the difference was computed in real time.

Accuracy data was collected in three modes:
1. Dockside comparison, long term (overnight).
2. Underway transit to site of station-keeping tests. The only specific maneuvers include 2 figure eight maneuvers to stress the dynamics of any possible GPS receiver filtering in the ship's system.
3. During DPS station-keeping tests to verify input to DPS during this test.

SUMMARY ACCURACY TESTS

Throughout all the testing we were able to log accuracy data. In addition to the figure eight maneuvers, we logged and analyzed the transit from the pier to the test area, as well the station-keeping tests.

TEST	Accuracy (meters 95%)	Duration (HH:MM:SS)
Transit to Test Area	**1.77**	**0:27:02**
First Figure Eight	**1.79**	**0:07:32**
Second Figure Eight	**1.31**	**0:07:53**
StationKeeping#1	**2.01**	**0:11:17**
Stand by in Test Area	**1.73**	**0:37:22**
StationKeeping#2	**1.76**	**0:12:29**
StationKeeping#3	**1.47**	**0:10:44**
StationKeeping#4	**0.90**	**0:10:59**
StationKeeping#5	**1.68**	**0:51:05**
StationKeeping#6	**3.18**	**0:31:42**
StationKeeping#7	**1.75**	**0:32:04**
Total Time		**4:00:10**
Average Accuracy*	**1.87**	

*accuracy weighted by duration of test

DGPS STATION-KEEPING TEST

The purpose of this test is to determine the capability of the ship to perform station-keeping using the ship's dynamic positioning system. The ships data was then compared in real time to both the RTK-GPS position for accuracy evaluation and the manually entered assigned position that the ship was to hold. The ship's master reference point (0,0) was used as the point on the ship to be positioned at the assigned position for this test. This was done to eliminate any possible disagreements over the use of position offsets to the buoy deck.

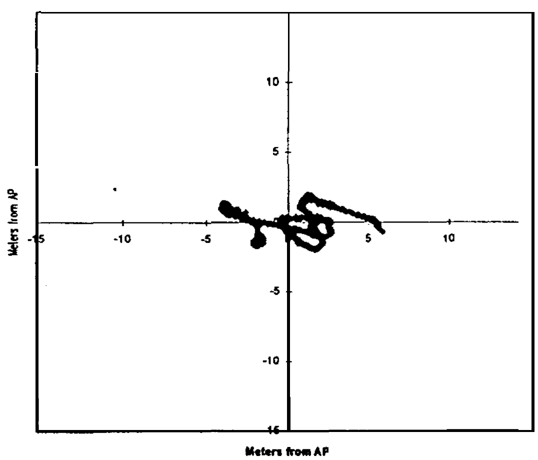
Data was collected in two modes:
1. Station-keeping to an assigned position for the ship's master reference point. Heading determined by DGPS.
2. Station-keeping to an assigned position for the ship's master reference point. Desired heading entered by conning officer to expose the vessel to different wind, wave and current angles.

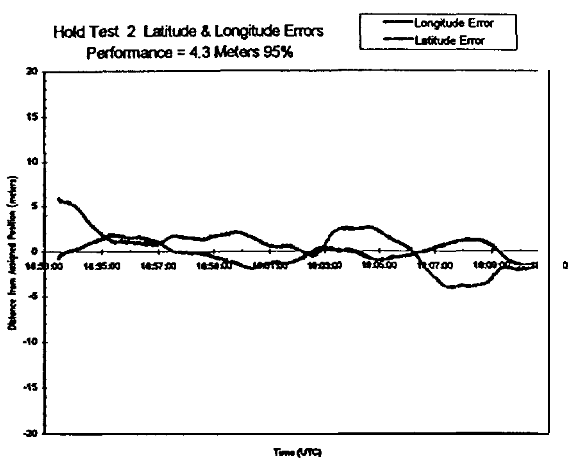
For each test there are three plots: First the XY scatter plot with the ship's position, based on RTK-GPS plotted relative to the desired hold position. Next is a combination plot with latitiude and longitude errors plotted on a time scale to show the dynamic positioning system's ability to converge and settle out on arrival and after the heading changes. The final plot for each test is the heading during each station-keeping exercise.

CONCLUSIONS

1. From the two days of underway accuracy testing conducted March 27,1996 and July 15,1996 from two different USCG differential GPS reference stations at distances of 3 to 100 nautical miles we arrive at the conclusion that the USCGC JUNIPER Differential GPS achieves the required 2 meter accuracy with a 95% probability.
2. Station-keeping tests revealed that the dynamic positioning system meets the 10 meter specification in moderate conditions. In most tests the DPS performance improved as the test proceeded. This indicated the control system needed some time to settle and model the external forces on the ship.
3. A major positive attribute of the system was that on every occasion where positioning performance was outside of the 10 meter limit the DPS raised the proper alarm indicating to the crew that the ship was not positioned properly. No false alarms were noted.

Hold Test 2 Performance = 4.3 Meters 95%





See *3rd Plot on page 7*

Navigation Information Service (NIS)

HOW TO REACH NIS

Write to:
Commanding Officer (NIS)
US Coast Guard Navigation Center
7323 Telegraph Rd
Alexandria VA 22315-3998
Telephone: 1-703-313-5900
Fax: 1-703-313-5920

Contact the BBS, call:
Telephone 1-703-313-5910
Modem speeds of 300 to 28,800 bps and most common U.S. or international protocols are supported. Communication parameters should be set to: 8 data bits, No parity, 1 stop bit, asynchronous comms, full duplex.

Internet:
Users can access the NIS at:
http: //www.navcen.uscg.mil
or
ftp://ftp.navcen.uscg.mil

E-mail:
nisws@smtp.navcen.uscg.mil

Fax on Demand (FOD):
Navigation Information is available through a Fax on Demand System 24 hours a day at:
Telephone 1-703-313-593 1/5932

NIS 24-Hour GPS/OMEGA Recording:
GPS: Telephone 1-703-313-5907
OMEGA: Telephone 1-703-313-5906

WWV/WWVH Radio Broadcast:
Users can hear WWV broadcasts by telephone or radio at 14-15 minutes past the hour and WWVH at 43-44 minutes past the hour.
Radio frequencies: 2.5,5,10,15,20 MHz
Telephone: 1-303-499-7111

Boating Safety Infoline:
Call Infoline operations for information on boating safety recalls, to report possible defects in boats, to comment on USCG boarding procedures, for answers to boating safety questions, or for boating safety literature.
Telephone: 1-800-368-5647

STATEMENT BY THE INTERNATIONAL OMEGA TECHNICAL COMMISSION ON THE FUTURE OF THE OMEGA NAVIGATION SYSTEM

The International Omega Technical Commission (IOTC), at its meeting in Melbourne, Australia in April 1996 considered the future of the Omega Navigation System.

The IOTC notes that:

(a) the US has developed the Omega navigation system, has met most of costs of establishing the system which comprises eight transmitting stations, and continues to meet a large proportion of the system operating costs
(b) the US Government has a bilateral agreement with each of the other six member agency governments which encompasses the operational and financial arrangements in respect to the station hosted by that government
(c) the US operates two Omega stations and fully meets the operating costs of one of the other stations
(d) three of the other member agency governments meet all the costs of operating their stations, and two meet part of the costs of operating their stations.

The IOTC understands that:

(a) the maritime need for Omega has declined to the point where the system is no longer required for navigation purposes
(b) most aviation needs for Omega have declined to the point where the system could be terminated in September 1997
(c) Omega is still being used for meteorological purposes
(d) most applications using Omega can be met by the Global Positioning System (GPS) or other systems

The IOTC notes that:

(a) The US position as stated in the 1994 US Federal Radionavigation Plan (FRP) is: "The US expects to continue Omega operations until September 30, 1997, to accommodate the transition of civil aviation users to GPS. Continued operation after that date will depend on validating requirements for Omega that cannot be met by GPS or another system." Thus far, no need for continued operation has been validated. However, the US Department of Transportation has formed a coalition to explore Omega sponsorship and funding beyond September 1997 by the weather community. The coalition report is due in May 1996. Meanwhile, since Omega bilateral agreements call for a one year formal notice of intent to terminate the agreement, the US is beginning the process that will result in delivery of such notice through diplomatic channels by 30 September 1996.
(b) Japan, recognizing the termination date suggested in FRP94, is ready for termination the Omega system on 30 September 1997, with the condition that at least the definitive decision for the termination should be made by 30 June 1996, because of the government budgetary procedures in Japan.
(c) Norwegian authorities will consider to cease Omega operations on 30 September 1997, provided a decision is made to terminate the system as of that date.
(d) Argentina in conjunction with the bilateral agreement with the United States, supports the termination of the Omega system on 30 September 1997, if the United States approves that date, or will honor the commitment to continue station operations.
(e) France has no opposition regarding a decision to stop Omega transmissions in September 1997. Nevertheless, if such a decision was taken, France would expect that the transmission of all stations would cease at the same time. If an alternative was settled and led to a decision to continue the current eight station Omega service in its primary function of navigation after September 1997, France would continue to operate its transmitter station.
(f) Australia proposes to cease operating its station on 30 September 1997, in the absence of satisfactory alternative funding.

The IOTC has considered the use which is begin make of the Omega system throughout the world for meteorological purposes, namely for upper air wind speed and wind direction measurements with radiosondes. The IOTC has concluded that:

(a) Alternative to Omega will be available for these meteorological applications, including radio systems such as Loran C (in some parts of the world), VLF (Very Low Frequency), and GPS.
(b) Additional costs and difficulties in collecting meteorological data will be incurred by users in changing over to alternative systems.
(c) It is possible that a simplified configuration of the Omega facilities could satisfy the meteorological requirements. This would need to be the subject of financial arrangements beyond the scope of IOTC responsibilities.

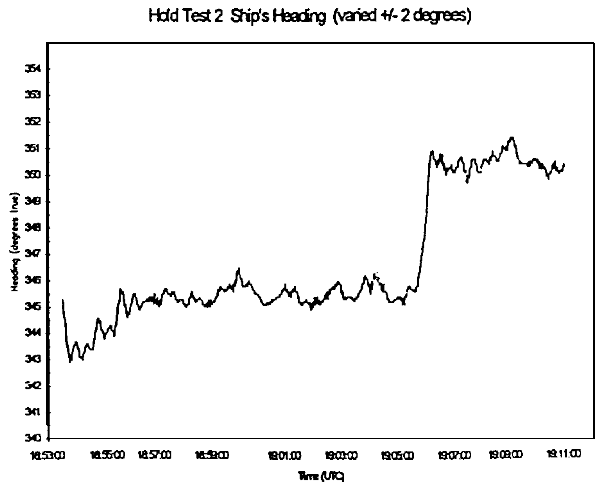
The IOTC agrees that:

(a) the termination of the Omega system should be orderly, as most user equipment requires signals to be received from a minimum of three stations
(b) as much notice as possible should be given of the proposed station closure dates, to minimize impact on the user community and station operating personnel
(c) it is desirable that all stations should cease operating on the same agreed date
(d) the statements in the 1994 US Federal Radionavigation Plan have already given adequate advance warning to users of the possible system termination date of 30 September 1997.

IOTC members have agreed to promptly advise relevant government agencies and primary user organizations in their respective countries of the strong possibility of the system being terminated on 30 September 1997.

IOTC will also arrange for this advice to be provided to the International Maritime Organization, the International Civil Aviation Organization, the International Association of Lighthouse Authorities, the World Meteorological Organization and the International Navigation Association.

3rd Plot from page 5



OMEGA

The author of the following three Omega articles presents several interesting and innovative ideas for modifying Omega stations after 30 September 1997. However, several key decisions have recently been made that may obviate the need for these changes. The US Meteorological Office has determined that it will not need the Omega system for weather prediction after 30 September 1997. Also, the US Federal Aviation Administration has similarly determined that Omega is not needed for aviation after the same date. The US has officially informed the Omega partner nations of the US commitment to discontinue operation of the two US Omega stations on 30 September 1997, and to conclude the bilateral agreements governing Omega operations. Although each partner nation is free to decide whether to continue its own Omega operations, all partner nations have indicated that they will follow the US lead and discontinue their operations on 30 September 1997.
-- Editorial Staff

OMEGA AS GOOD AS GPS

The U.S. Air Force does hurricane tracking under contract for the National Weather Service. Part of this operation involves flying over the hurricane and dropping in radiosondes which measure meteorological characteristics and relay this information back for processing. The radiosonde is tracked by Omega signals, and the change in position of the sonde over time determines the wind speed and direction at that altitude. Weather ballons operate in essentially the same way.

Omega is used because the receiver is very simple and therefore low cost; radsiosondes using GPS are considerably more expensive. Considering that radiosondes are not recoverable after one use, and the large number used, Omega offers a significant cost advantage.

Hurricane tracking is extremely important, particularly to predict a hurricane's landfall. This allows timely preparations

See *Omega on page 9*

DGPS UPDATE

The Coast Guard Differential GPS has entered its Initial Operational Capability (IOC) phase. Seventeen sites are being monitored and controlled by the West Coast Control Station in Petaluma, California, and thirty-four sites are monitored and controlled by the East Coast Control Station located at the Navigation Center in Alexandria, Virginia. Puerto Rico remains to be connected to the control network though it is transmitting corrections. Construction has begun on the site in Key West, Florida.

The Army Corps of Engineers are adding more sites to the DGPS network. Preliminary ground work is being done for future sites at Reedy Point, Delaware; Louisville, Kentucky; and Omaha, Nebraska. Coordination with the Federal Aviation Administration has to be completed to ensure the DGPS broadcasts do not interfere with the aerobeacons at airports in those cities.

LTJG V. Bauer, NAVCEN

REPORTING DGPS DISCREPANCIES

If you have experienced a problem using the Coast Guard DGPS Service, we would like to know about it. Please make a report to the NIS by phone, e-mail or fax. (*See "How to Reach NIS" on page 6.*)

There are some specific questions we'd like you to answer in your report. Here is an example of what our DGPS User Outage Report looks like:

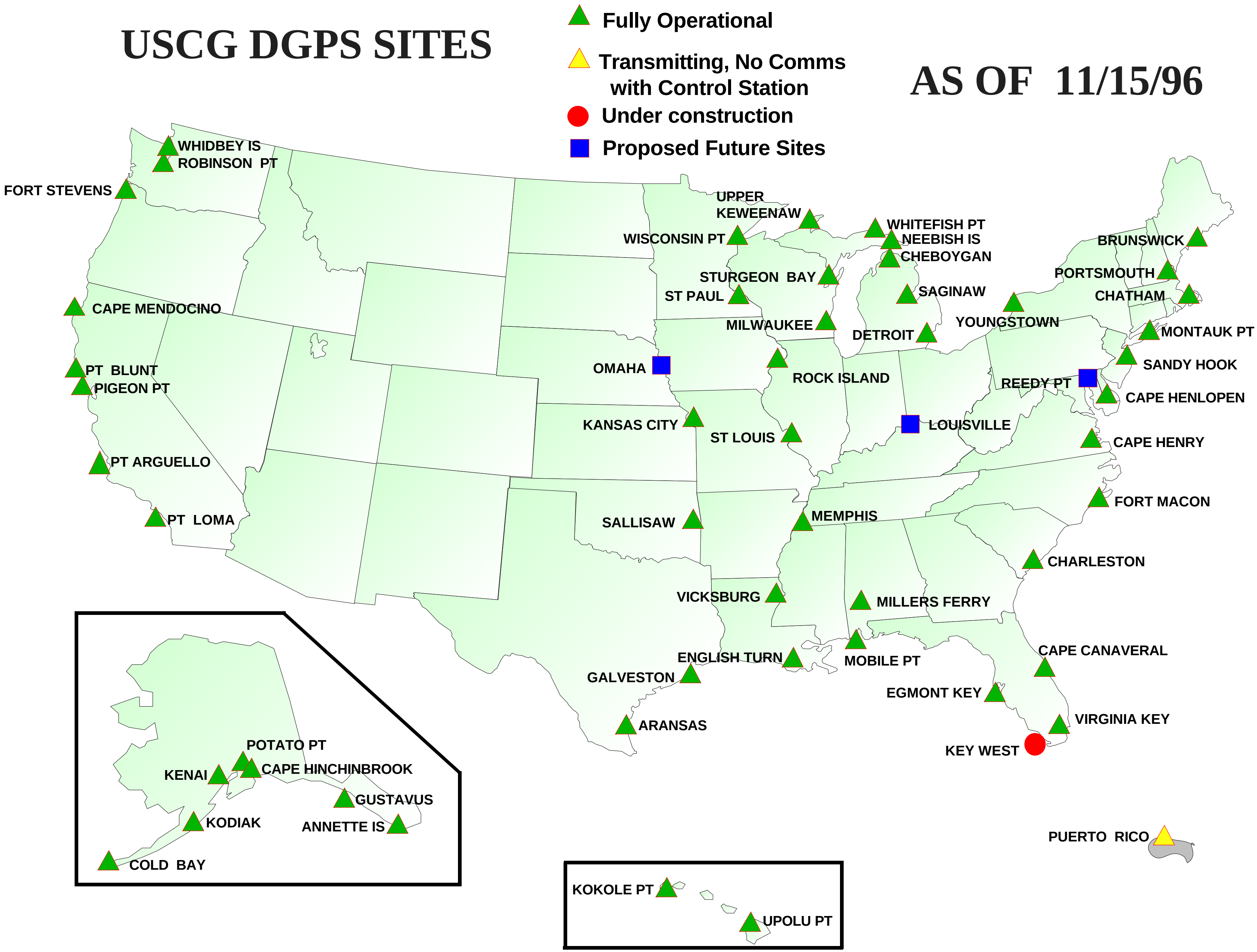
Date 22OCT96
Vessel/Unit/Person's Name: Intrepid II
General Geographic Location: Ft Lauderdale FL
Vessel Position: Latitude: 260719" N Longitude 8008'37" W
Vessel Activity: Moored
Weather Conditions : Wind: West , 35-45kts Sea State: Calm
Temp: 80 F Visibility: 10 nm
Bearing and range (approx) to electrical storm: NONE
Time of Outage: 1100 AM 21 OCT96 to 1030 AM 22OCT96
Did GPS work? Yes Number of satellites tracked on GPS receiver: 6
DGPS/Radiobeacon Site Using: Virginia Key (Miami)
Normal Radiobeacon Operational: Was stated in operation
22OCT96 - DGPS Status from NIS BBS
DGPS Beacon Receiver Signal Strength (SS) Reading: NONE
DGPS Beacon Signal to Noise Ratio (SNR) Reading: NONE
Point of Contact: Name: Adam Josef
Phone Number: 305123-4567
Comments: ____________________

LTJG V. Bauer, NAVCEN

DGPS Status can be obtained from the NIS internet access and the NIS BBS:

Internet:
http://www.navcen.uscg.mil
or
ftp://ftp.navcen.uscg.mil

BBS: Modem Telephone: 1-703-313-5910



USCG DGPS SITES
AS OF 11/15/96
Fully Operational
Transmitting, No Comms with Control Station
Under construction
Proposed Future Sites
WHIDBEY IS
ROBINSON PT
FORT STEVENS
CAPE MENDOCINO
PT BLUNT
PIGEON PT
PT ARGUELLO
PT LOMA
UPPER KEWEENAW
WISCONSIN PT
STURGEON BAY
ST PAUL
MILWAUKEE
OMAHA
ROCK ISLAND
KANSAS CITY
ST LOUIS
SALLISAW
MEMPHIS
VICKSBURG
ENGLISH TURN
GALVESTON
ARANSAS
WHITEFISH PT
NEEBISH IS
CHEBOYGAN
SAGINAW
DETROIT
YOUNGSTOWN
LOUISVILLE
MILLERS FERRY
MOBILE PT
EGMONT KEY
KEY WEST
VIRGINIA KEY
CAPE CANAVERAL
CHARLESTON
FORT MACON
CAPE HENRY
CAPE HENLOPEN
REEDY PT
SANDY HOOK
MONTAUK PT
CHATHAM
PORTSMOUTH
BRUNSWICK
PUERTO RICO
POTATO PT
KENAI
CAPE HINCHINBROOK
GUSTAVUS
KODIAK
ANNETTE IS
COLD BAY
KOKOLE PT
UPOLU PT

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for evacuation of vulnerable remote areas, as well as proper protection of remaining structures. Estimates of the cost exposure for inaccuracies in prediction of hurricane landfall are $1 million per mile of error. This reflects the cost of both needless protection efforts and evacuations and resulting loss and damage where evacuation or protection was not carried out when needed.

During Hurricane Bertha in early July 1996, the Air Force carried out a test that used a few (much more expensive) GPS sondes along with the ususal Omega sondes. They reported that both types of sondes tracked very well, giving essentially the same data. This is despite the common belief that GPS provides much better accuracy than Omega.

Determining wind speed and direction is done essentially by measuring the position of the sonde at two sequential times and calculating the rate of change. Changes in phase are measured over time from at least three Omega stations and geometrically combined to obtain the wind vector. Since these measurements are taken in quick succession, factors which normally reduce the absolute position accuracy of Omega are eliminated. These factors include the predictable periodic propagation variations, unpredictable short-term PCDs (Polar Cap Disturbances) and SIDs (Sudden Ionospheric Disturbances), and even overall system synchronization. For weather ballon use, Omega radiosondes also are not as sensitive as GPS sondes to normal swinging of the sonde below the weather balloon which adds position "noise" to GPS wind measurements. Therefore, actual results have shown that for windfinding applications, the much-lower-cost Omega system is as good as, if not better than, GPS.

VLF WITHOUT OMEGA

When the Omega Navigation System is terminated in September 1997, many present users of the system are planning to continue using Navy VLF communications transmissions for tracking, instead of the more expensive GPS. VLF communications transmissions are currently used to augment the Omega network and improve overall system redundancy and reliability. Yet the Navy has discouraged the use of their VLF signals for tracking - retaining the right to make changes without warning, which has occurred. Of particular concern to tracking users is an operation called TACAMO, in which the VLF transmission is no longer from a known, fixed point, but instead from a moving aircraft.

The computer in the tracking system determines position or change in position as a function of phase changes in the received signals originating from known (assumed fixed) locations. If one or more of those assumed fixed positions is either in a different position or moving around, it can confuse the computer and cause erroneous results.

Since the Navy is unlikely to provide advance information about TACAMO operations, anyone using VLF for tracking may want to consider setting up a fixed reference monitoring station, in which the phases from all the VLF transmissions to be used are monitored. If these phases "stand still" (within the normal predictable periodic variations characteristic of VLF propagation), then those signals are usable for tracking. If one or more of them start "moving around," those frequencies should be removed from the position determination algorithm.

Because of the long-distance characteristics of VLF propagation, a single reference monitor should be adequate for a very large area, perhaps even worldwide.

SIMPLIFICATION OF OMEGA TRANSMITTING FACILITIES FOR VLF TRACKING

A major remaining user of the Omega system is the meteorological community which uses it for tracking weather balloons. After termination of Omega, they are considering using simple, inexpensive VLF radiosondes for tracking instead of much more expensive GPS radiosondes. The nature of Omega/VLF tracking of weather balloons only requires a phase-stable signal (as opposed to the complete Omega format), which is why VLF stations can also be used. There are, however, problems with VLF, including unpredictability of signal characteristics (see related article), plus the majority of VLF stations are in the northern hemisphere, a problem for users in the southern hemisphere, particularly for Antarctic research.

Omega stations contain transmitting equipment and 1200-1400 ft towers that are capable of transmitting phase-stable signals suitable for weather balloon tracking, but at a much lower cost than required for transmitting the full Omega format. This is a resource which will be hard to duplicate if the equipment and towers are dismantled following Omega system turnoff.

A simplified system of this type suitable for weather balloon tracking would not require systemwide synchronization or the complex electromechanical antenna switching system presently required for transmitting the five Omega frequencies. These minimal requirements eliminate the need for a large staff of personnel both at the stations and for support, as well as the elimination of expensive, high-maintenance, high voltage vacuum relay cells. Augmentation of the worldwide VLF stations for weather balloon tracking may require only one or two additional former Omega facilities, rather than all eight, and it is possible they could be unattended (or at least require a lot fewer personnel), resulting in greatly reduced operating costs.

Although fully adequate for weather balloon tracking needs, such a system would not be usable for position determination as is presently possible with Omega, and it would not be part of the worldwide Omega partnership as we know it today.

A paper describing more details of this approach was submitted to the International Navigation Association and should appear in the Proceedings of their August 1996 meeting.

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